Forecasting Seed Crops and Determining Cone Ripeness in Southwestern Ponderosa Pine

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Abstract

Cone crop forecasting is important for planning regeneration cuttings and seed collections. Knowledge of time and rate of flower and cone development is essential. An early July flower and conelet inspection serves two purposes: (1) a flower count detects 15 months in advance the possibility of a cone crop the following year; (2) a conelet count checks progress of the current year's cone crop. Flower and conelet observations and cone collections should be made on dominant trees larger than 12 inches d.b.h. A population mean cone specific gravity of 0.88 coincides with the time 80% of the seeds are mature. When 13 or more of 25 cones in a sample float in SAE 10W or 20-20W motor oil, it is safe to begin collections in the area sampled.

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Management Implications

Both natural and artificial regeneration depend upon seed supply, which varies from year to year. If the relative number of ponderosa pine flowers could be used to estimate potential yield of cones 15 months in advance, and were verified 3 months before seedfall, it would help planning in several operational phases of forestry. Seedbed preparation and timber harvesting could be timed with seed crops to ensure adequate natural regeneration. Because heavier seed crops contain the best quality seed (Fowells and Schubert 1956, Larson and Schubert 1970) and can be collected at lower cost, plans can be made to collect ample seed for artificial regeneration during favorable seed years (fig. 1). Good pine seed can be stored without serious loss of viability for at least 2-5 years (Fowells and Schubert 1956).

Figure 1.—A heavy ponderosa pine cone crop shedding seed in mid-October. Medium to heavy cone crops are relatively easy to forecast, and should be favored for seed collection.

Phenology of Flowering and Cone Development

Understanding the time and rate of development of flowers and cones, and recognizing certain stages of development at certain times, we can estimate the size of a cone crop up to 15 months in advance and monitor its progress. Phenology involves timing of plant growth, and development with seasonal changes in climate. Timing of the flowering and fruiting process in ponderosa pine is very closely tied with climatic changes during the year.

The general sequence and phenology of flowering and conelet development in southwestern ponderosa pine is outlined in table 1.[2] Portions of three years are required in development of a future cone crop: (1) initiation of floral primordia in the first year, (2) development of flowers and conelets the second year, and (3) fertilization and maturation of cones in the third year.

[2] *More detailed descriptions of flowering and conelet development in* Pinus *can be found in Gifford and Mirow (1960), Kozlowski (1971), and USDA (1974).*

Table 1.—Sequence and timing of events of flowering and conelet development of southwestern ponderosa pine.[1]

Event	Month of occurrence or duration	Elapsed time *(months)*	
		From primordia	From flowers
Flower primordia are differentiated in buds	August	0	
Male and female flowers first become visible on elongating shoots (fig. 2)	June	10	0
Pollination and pollen tube development	Mid-June—early July	10.5	0.5
Resting period (fig. 3)	July—May	21	11
Fertilization	June	22	12
Post-fertilization cone enlargement	June—mid-Sept	24.5	14.5
Cone and seed maturation	Late Sept—Oct	25.5	15.5
Cone opening	Mid-Oct—Nov	26	16

[1] *Data assembled from Pearson (1931), personal communication with Dr. John A. Pitcher (Regional Geneticist, USDA For. Serv. R-3), and personal observations.*

Both male and female flowers occur separately on the same tree. Male and female flower primordia—microscopic stages of the flowers—are formed in the winter buds at the end of the growing season. Flowers first become visible to the eye the following spring when they emerge from expanding buds. Male flowers (fig. 2a) usually appear one to two weeks before the females. They form at the base of the current year's growth, mostly on older lateral branches in the lower crown. Female flowers (fig. 2b) appear at the tips of the current year's branch growth, usually in the upper crown at the ends of the main branches.

a

b

Figure 2.—(a) Male flowers of southwestern ponderosa pine nearly ready to release pollen, and(b) female flowers nearing receptivity in mid-June. The male flowers appear first; note their location at the base of the new shoot. The female flowers appear in groups of one to five near the tip of the new shoot.

Male flowers occur in clusters of a few to 30 (fig. 2a). Before ripening they are usually green, but somethimes have a reddish tinge. They are yellow to light brown at the time pollen is shed, and then turn brown. Female flowers are usually green (fig. 2b), but sometimes they are red to purple. At the time of pollination, female flowers are about one-half inch long. The flowering period lasts about three weeks. Male flowers fall soon after pollen is shed, while the pollinated female flowers develop slowly and eventually become the mature cones.

It is important to note that floral initiation varies as much as 2-3 weeks and varies in different parts of the forest and the region, depending on weather and site conditions.

Pollen tubes initially develop rapidly, then rest for several months. By fall, conelets are still quite small—only about one-tenth the size of mature cones (fig. 3). Pollen tube development is completed, and fertilization takes place in early summer the following year.

Conelets enlarge rapidly following fertilization and become full-size cones by mid-September. Growth of the new shoot places the developing cones in a lateral position. As cones mature, they gradually change from green to brown.

Figure 3.—Conelets in mid-October are very small and difficult to see from the ground. They are dormant in winter. Pollen tube development will be completed early the following spring, fertilization will occur, and the ovulate (fertilized) conelets will enlarge rapidly during the summer and mature in the fall.

It is uncertain how much the time of seed maturity varies with elevation, but the time of cone opening depends on the drying conditions at different locales. Both seed maturity and cone opening vary considerably with different seed crops. The elapsed time for initiation of floral primordia to cone maturity is approximately 26 to 27 months, and from flower initiation to cone maturity it is 15 to 16 months.

Forecasting and Rating Methods

Timely observations of female flowers and developing ovulate conelets are the basis for forecasting probability of a good seed crop. The key factors are: (1) when and how the trees are observed, (2) what is looked for, and (3) how what is seen is translated into a cone crop prediction. These factors are the basis for a cone crop forecasting and rating system. Since, the third factor already has been dealt with (Schubert and Pitcher 1973), the first two will be emphasized.

With practice, it is not difficult to spot and count (using binoculars) the female flowers on the elongating shoots of trees up to 50 feet tall. The main interest is in the female flowers before they become cones. It is best to observe the trees in early July because any female flowers have appeared by that time and are not yet obscured by needles (fig. 2b). After late July, the elongating needle fascicles on the new shoots hide the conelets. Also, in early July the fertilized, enlarging ovulate conelets below the base of the current year's growth can be counted. These will be slightly larger than those pictured in figure 3, and will be the current year's cone crop.

The early July inspection serves two purposes: (1) to estimate the potential cone crop for the following year (15 months in advance), and (2) to monitor the progress of the current year's cone crop (3 months in advance). It is recommended that the forester responsible for regeneration on each District go into the field in early July of each year (with binoculars and data sheet) to make the observations needed for cone crop forecasts. Additional observations are desirable when a good cone crop is in progress, and the rapidly enlarging cones become easier to count.

The next considerations are: (1) which trees to observe, (2) how the cone crop rating system works, and (3) what size a worthwhile cone crop is. Dominant trees over 12 inches in diameter with full, vigorous crowns are considered to be good seed trees (Schubert and Pitcher 1973). Dominant trees over 19.5 inches d.b.h. are the best seed producers (Fowells and Schubert 1956), but are difficult to observe and collect from unless a timber sale can be scheduled at the time cones are ripe (about a 3- to 4-week period).

The 10-unit cone crop rating system (table 2) recommended by Schubert and Pitcher (1973) has been used successfully in California since 1955. It is based on a spring or early summer conelet inventory of dominant trees over 12 inches in diameter, which is a 3- to 5-month forecast of the size of the current cone crop. At least 10 trees should be inventoried in a proposed

Table 2.—The 10-unit classification for rating cone crops on conifers in Arizona and New Mexico (from Schubert and Pitcher 1973).

Classification	Description[1]
1 None	No cones on any seed tree.
2 Very light	Few cones on less than one-fourth of the seed trees.
3 Very light to light	Few cones on one-fourth to one-half of the seed trees.
4 Light	Few cones on more than one-half of the seed trees.
5 Light to medium	Few cones on more than one-half and many cones on less than one-fourth of the seed trees.
6 Medium	Many cones on one-fourth to one-half of the seed trees.
7 Medium to heavy	Many cones on more than one-half of the seed trees.
8 Heavy	Many cones on more than one-half of the seed trees, with less than one-fourth to one-half of them loaded with cones.
9 Heavy to very heavy	Many cones on more than one-half of the seed trees, with one-fourth to one-half of them loaded with cones.
10 Very heavy	Many cones on more than one-half of the seed trees, with more than half of them loaded with cones.

[1] *Cones per tree: few = 1 to 20; many = 21 to 160; loaded = 161 or more.*

collection area to give an accuate estimate of the crop. Both female flowers and ovulate conelets should be inventoried in early July, and both current cone crop and next year's cone crop should be rated according to the system in table 2. For a single cone crop, this approach gives both an advance indication (15 months) and current forecast (3 months) of cone crops to provide maximum time for planning. It is further recommended that flower and conelet observations and cone crop forecasts be made for the individual tree seed-zones proposed by Schubert and Pitcher (1973). Forecasts may not be necessary for all seed-zones, only for those where seed or seeding is needed.

Although female flowers are more difficult to see and count than developing cones, the forester should persevere and make the best flower counts he can. The flower count is very important since it detects the beginning of a cone crop well in advance and gives an estimate of its possible size. This allows adequate time to watch the cone crop and plan cultural treatments and collections as it materializes.

When few or no female flowers are observed in early July, it can be concluded that there will be no local cone crop the following year. When a significant number of flowers per tree are counted, it must be remembered that the conelet count almost always will be lower than the flower count because of such factors as flower and conelet abortion, insects, and severe late freezes. Severe freezes during the flowering/pollination period are

uncommon, but may inflict severe losses when they occur. Abert squirrels may destroy 25% or more of the conelets or cones (Larson and Schubert 1970). Cone insects and squirrels are usually more of a problem to light to moderate cone crops. The point to remember is that moderate attrition of flowers, conelets, and cones is to be expected, and total crop failures are not unusual.

Only medium to heavy cone crops should be considered for seed collections. Smaller cone crops might be utilized for regeneration cuttings, but the risk of failure is greater. The best seed, in terms of soundness and viability, is produced in heavier seed crops (Fowells and Schubert 1956, Larson and Schubert 1970). During heavy seed crops, cone losses to squirrels and insects, and seed consumption on the ground by rodents and squirrels are less serious, leaving a greater proportion of the seed crop for collection or natural regeneration. Collection costs are lower during heavy seed years. Enough seed can be collected and stored from heavier seed crops to supply the needs during the years of poor seed crops.

Additional information on cone production and seed characteristics in southwestern ponderosa pine may be found in Larson and Schubert (1970), Schubert and Pitcher (1973), and Schubert (1974). Larson and Schubert (1970) developed a method to predict cone crop size based on counting conelets on twigs clipped by squirrels. This method is useful to detect and monitor the progress of a cone crop where squirrels are active.

Determining Cone Maturity

Cones and seeds of southwestern ponderosa pine mature several weeks before normal cone opening. Present collection methods are based on picking closed cones during the period between cone (seed) maturity and seed shed. If only a small amount of seed is needed, the best time to collect is when the cones on some trees are beginning to open. By that time, seeds have matured in other trees with closed cones. At best, the time available to collect closed cones using this approach is only a week to 10 days, limiting the amount of seed that can be collected.

To obtain a large amount of seed for regeneration programs, it is necessary to determine the earliest date when an acceptable degree of seed maturity has occured so that mature seed can be collected for a maximum time before the cones open.

The relationship between declining cone specific gravity (cone density, primarily due to moisture content) and increasing seed germination has been applied in other regions as an index to seed maturity (Maki 1940, Schubert 1955, Stoeckeler and Slabaugh 1965, and Van Deusen and Beagle 1973). A study of the cone specific gravity-seed maturity relationship was recently completed for southwestern ponderosa pine.[3] The experimental

[3] *Rietveld, W. J. Cone specific gravity as a seed maturity index for southwestern ponderosa pine. (Manuscript in preparation).*

methods and technical interpretations will be presented in that paper; only the application with be discussed here.

Because climatic factors that affect germination vary from year to year, and local environment affects seed development on individual trees, cones cannot be expected to mature on the same date each year, nor can all trees be expected to mature cones at the same time. One reliable factor, however, is that the specific gravity of the cones will decrease with time, and the enclosed seeds will be closer to maturity. This relationship between declining cone specific gravity and increasing seed maturity will hold true from year to year, since it is independent of the calendar year.

When a certain mean cone specific gravity is reached in a stand, a certain percentage of seed viability can be expected when cones are collected from all trees in that stand. Note that the specific gravity-cone maturity relationship holds true for the cones in a population of trees, not for the population of cones in a single tree. Because cones on different trees may resist moisture loss or dry prematurely due to differences in thickness of cuticle, exposure, or surface area, the relationship in individual trees may not follow exactly the same pattern as the mean of the population. Thus, early collections of cones from "mature" individual trees which pass the test will yield a lower proportion of mature seeds than indicated by their cone specific gravity. It is best, and much easier, to wait until the population mean cone specific gravity goes below 0.88, and then collect cones from the entire stand of trees.

Progress of seed maturity in a sample of 30 trees is shown for the period September 9 to November 6, 1974 (fig. 4). Sampling began on September 9, at that time, 28.7% of the trees yielded mature seeds. By September 30, 73.4% bore mature cones and seed. Most of the trees, 93.3%,matured their cones by October 10. If collections were begun when the minimum acceptable viability of filled seed was 80%, this proportion of the trees would have mature cones on October 4, 1974. This minimum 80% seed viability coincided with a population mean cone specific gravity of 0.88 in 1974 (see footnote 2). On a given date, cone specific gravity did not vary significantly for cones on a single tree, but did vary widely among trees. Therefore, it is important that an adequate number of trees be sampled to obtain an accurate estimate of mean cone specific gravity.

The floatation test, where cones are floated in a test fluid, is recommended for use in the Southwest. The specific gravity of the test fluid must be equivalent to the critical value for cone ripeness. SAE 10W and 20-20W motor oils have a specific gravity of about 0.88 at 60°F.[4] Approximately 2 quarts in a sealable container is enough to conduct the test.

When 13 or more of a sample of 25 cones float in oil, it is safe to begin collections. Because variation in cone specific gravity within a tree is small

[4] *Specific gravity of SAE 10W and 20-20W varies between 0.87 and 0.89 depending on the manufacturer and application. Truck engine oils have slightly higher specific gravity.*

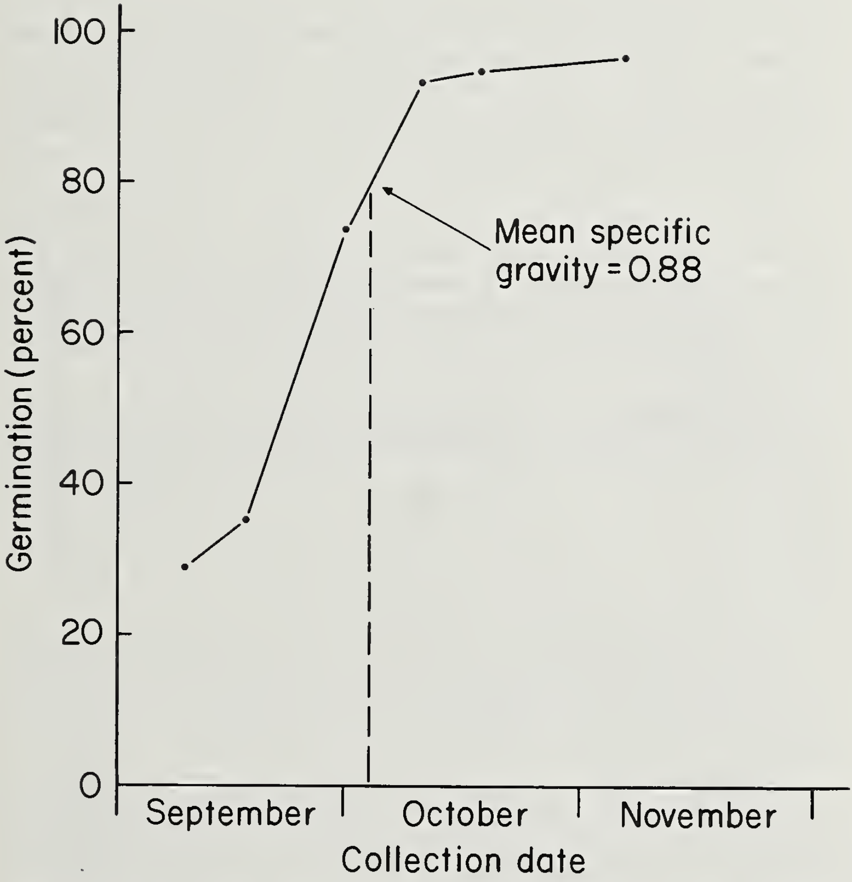

Figure 4.—Seed viability increased rapidly from mid-September to early October. Mean cone specific gravity was 0.88, and 80% of the seed were mature on October 4, (dashed line), the time to begin collecting in 1974. In other seed years, the seed viability line will have the same shape, but will shift to the left or right, depending on growing conditions. The date to begin collecting can vary two weeks or more in different years, and the period to cone opening may vary from 2 to 6 weeks.

and variation among trees is large, one cone should be sampled from each of 25 trees scattered over the area. It is convenient to first collect the 25 cones, seal them in a plastic bag to prevent excessive drying, and test them within 2 hours. Cones should be free of stems, needles, dirt, etc., when tested. When any part of a cone breaks the surface of the test fluid, it is counted as a "floater." Those that sink have a specific gravity greater than 0.88, and may be retrieved with an ice pick.

The area of application of a single cone maturity test is uncertain. Until specific information is available, a cone maturity test should be restricted to no more than one square mile within a continuous timber type and 500 feet of elevation change.

The drying trend of cones is slow at first, and cone specific gravity persists at fairly high levels, averaging around 1.00. At some point (mid-September in 1974) the cones "die" and then dry very rapidly. When this stage is entered, more frequent floatation tests are needed. Rainfall during this period slows the drying trend only briefly; in 1 or 2 days the cone drying trend resumes.

During the moderately wet fall of 1974, the cone collection period extended from October 4 to mid-November. Cones on some trees began opening by November 6, but many trees had closed cones as late as November 15. Under hot, dry, windy fall conditions, the cone collection period may be reduced to as little as 2 to 3 weeks, and collections must begin promptly after average cone specific gravity for the stand reaches the critical value.

Some precaution is necessary when gathering seed on logging operations. It is imperative that the float test be applied only to cones freshly picked from newly-felled trees; cones dry out rapidly on felled trees, and after a few hours their specific gravity is meaningless. Either logging should wait until the cones are judged to be sufficiently mature for collection, or cone collections should wait until mean specific gravity of cones obtained from freshly fallen trees is below the critical value.

There is little difference in the appearance of cones collected too early, say mid-September, and mature cones collected in early October, but low germination and poor storage characteristics of September collections are unacceptable (fig. 4).

It may appear to be a feasible alternative to simply begin cone collection in early October each year, rather than become involved in sampling and floatation tests. However, because of variables such as time of fertilization and climatic conditions during development, the time of 80% seed maturity may vary as much as 3 weeks in successive cone crops. Collections may begin too soon, when much of the seed is immature, or too late, resulting in a shortened collection period. Under prudent management, best efficiency of collection and highest seed quality are attained by collecting during heavier seed years and carefully applying the cone ripeness criterion.

Summary

Cone crop forecasting is needed to help plan regeneration cuttings and seed collections. Heavier seed crops should be favored because seed is of higher quality and easier to collect.

Knowledge of the sequence and timing of development of flowers and crops is basic to cone crop forecasting. The development of a cone crop is described from primordia in buds, to visible flowers, to fertilized ovulate conelets, to mature cones. Female flowers and ovulate cones are the subjects of the field observations.

Early July is the best time to observe the trees (dominants larger than 12 inches d.b.h.) for both female flowers and ovulate conelets. The flower count estimates the potential cone crop for the following year 15 months in advance, and the conelet count estimates the progress of the current year's cone crop 3 months in advance of cone maturity. The 10-unit cone crop rating system should be used for both flower and cone counts; considerable flower and conelet mortality may subsequently reduce the ratings, of course. Forecasts should be made for individual seed zones where seed or seeding is needed.

A cone maturity index is needed to determine the earliest date an acceptable percentage of trees have mature cones and collections may begin. A study of the 1974 cone crop indicated that a population mean cone specific gravity of 0.88 coincided with seed maturity in 80% of the trees—the minimum acceptable maturity. The time when cone collections can begin is determined by a floatation test. When 13 or more of a sample of 25 cones float in SAE 10W or 20-20W motor oil, it is safe to begin collection in the area sampled.

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Keywords: *Pinus ponderosa,* cone crops, phenology.

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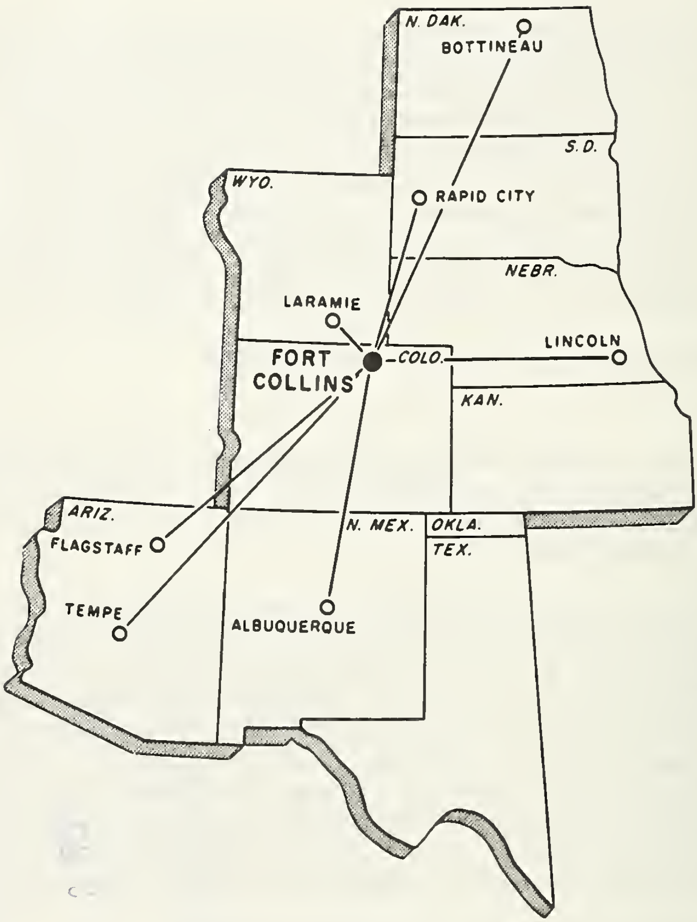
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